Development of a Cursor Control Device for Space Flight Operations

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Future spacecrafts will be primarily controlled through "glass cockpits" with software displays rather than hardware switches and buttons. Human factors researchers at NASA Johnson Space Center have worked for a number of years in research and development to determine the best cursor control device (CCD) for space flight operations. The device must work under vibration and acceleration, in microgravity, and ungloved and gloved (with and without pressure). Crew performance will depend greatly on the intuitiveness and ease of use of the CCD selected/designed for future missions.

Past Work

During the early 1990s, NASA conducted several CCD evaluations in the laboratory, on the KC-135 reduced-gravity aircraft, and during space shuttle missions STS-29 and STS-41. The goal was to gather data to determine the best CCD design characteristics for use in microgravity. These results ultimately serve as a starting point for future research with the Constellation Program. Standard devices such as a trackball and mouse, as well as a variety of other commercial and prototype devices, were tested using custom experimental software that recorded response times and errors. An optical mouse proved to be the fastest device in a variety of environments, but it was not a good choice for the microgravity environment due to the number of separate components. The trackball provided good performance, and had the advantage of being a fixed, one-piece design that did not require a work surface.

Constellation and the Orion Crew Exploration Vehicle

As the Constellation Program began, there was renewed interest in developing a CCD for space flight. Starting with design characteristics determined from the earlier CCD work and the knowledge that any new design had to accommodate the 1st- to 99th-percentile hand breadth and length, researchers began testing commercially available devices using a CCD test battery developed through Human Research Program funding. The CCD test battery employed cursor control tasks described in the ISO [International Standards Organization] 9241-9 standard, as well as tasks from previous studies conducted in microgravity.

In 2007, a laboratory study compared performance of nine commercial and proprietary devices with and without extravehicular activity gloves. In general, the trackball devices showed the best performance, and data were used to down-select devices for future studies. Since pressurized gloves impact gripping ability and tactility, an early concern was performance in a pressurized spacesuit. Thus, an engineering test was performed in a pressurized glove

Fig. 1. *Cursor control device prototypes.*

Fig. 2. *Pressurized glovebox study.*
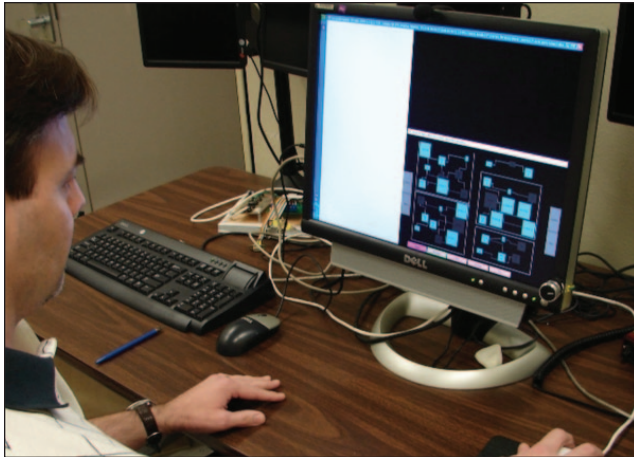
Fig. 3. Laboratory study.
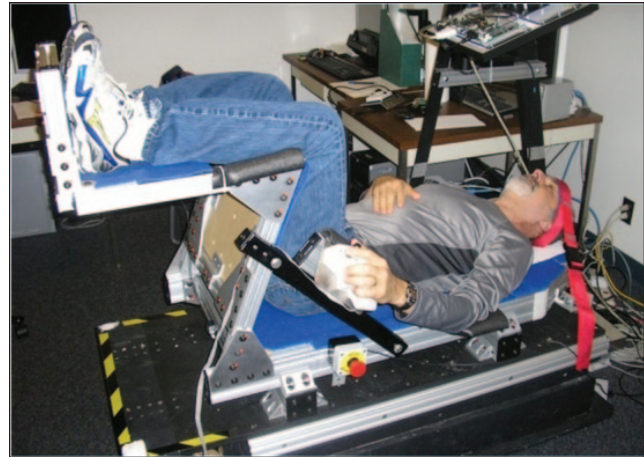

Fig. 4. Vibration study.

box to identify basic types of hand and finger positions as well as motions that worked best under pressure. Device components that were problematic with pressurized gloves were dropped from further consideration.

A 2008 laboratory study examined the type of cursor movement (continuous vs. discrete) and experimentally compared a trackball, cursor knob, castle switch, and scroll wheel. All devices were operated with the participant's left hand (Orion requirement) while wearing an unpressurized glove (without a thermal micrometeoroid garment). Participants performed best with the trackball in continuous mode and castle switch in four-way discrete mode in terms of movement time and accuracy.

The trackball and castle switch were then tested in 2009 with two new device prototypes: (1) a large, continuous, castle-type switch that was modeled after an F-18 aircraft control; and (2) a rocker switch. The trackball, castle switch, and F-18 device were tested in two- and four-way discrete modes; the rocker switch could only operate in two-way discrete mode. Results indicated that participants had the best performance with the rocker switch, the trackball in four-way mode, and the castle switch in four-way mode in terms of response times, with the castle switch having the lowest error rate. Results of these studies were used by the Cockpit Working Group to make design decisions about the CCD for Orion. See figures 1 and 2.

Testing Under Extreme Conditions
Some concerns were expressed about the use of the CCD under vibration, such as during launch, in the course of its development. Accordingly, in 2010 NASA performed a study in the Ames Research Center Vibration Facility to determine characteristics of CCDs that perform well or

are problematic under different levels of vibration. The vibration platform provided one axis of vibration (X axis/chest to spine) at various amplitudes and frequencies. Displays for the CCD tasks were shown on a monitor mounted in a fixed position at viewing distance above the participant's head; the monitor did not vibrate. CCDs were mounted on the chair for left-handed use as planned for Orion.

The trackball was tested in continuous and four-way discrete mode, the castle in two- and four-way discrete mode, and the rocker switch in two-way discrete mode. For all devices, the vibration conditions with higher amplitudes (3 Hz 0.17g, 6 Hz 0.35g and 12 Hz 0.70g) affected performance; lower amplitude vibrations did not cause a significant decrement in performance as compared to performance with no vibration. Response times for the two-way devices were negatively impacted by vibration, while four-way and continuous modes were not. Further research is warranted to confirm/clarify these results. See figures 3 and 4.

Conclusions
A CCD for the space environment must be accurate and efficient under a variety of challenging environmental conditions. The described body of research suggests the following: when high accuracy is required (e.g., vehicle commanding), consider CCD solutions such as the castle switch and rocker switch with a discrete cursor movement type, and the trackball for applications in which errors do not have a serious safety consequence (e.g., standard computer use in a vehicle or space-based habitat).